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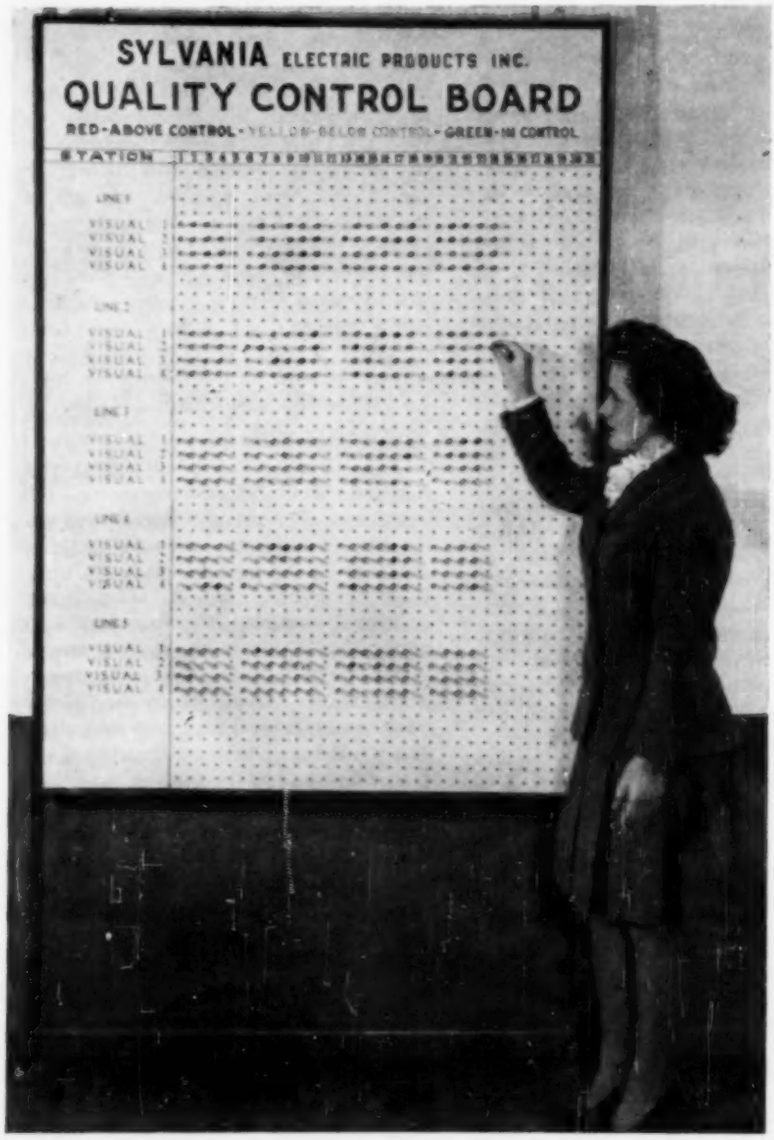

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THE COVER PICTURE

The Sylvania Peg Board employs color to vivify control in fraction defective charting. Green means "in control," red "out on the high side," and yellow "out on the low side."

SOCIETY OF QUALITY CONTROL ENGINEERS
IN COOPERATION WITH
THE UNIVERSITY OF BUFFALO

INDUSTRIAL QUALITY CONTROL
Editor: Martin A. Brumbaugh,
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Buffalo 14, New York

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COST OF BACK ISSUES

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Martin A. Brumbaugh, Editor
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EDITORIAL

Much publicity has been given to the wonderful inventions and discoveries made during the war. Some of these new developments have been over advertised, others will perform fully as well as their advance press notices indicate. Machining methods, chemical processes, applications of electric power, Roentgenray methods of testing and inspection, textile coatings, measurement devices of greatly superior accuracy, sensitivity and fineness of calibration, all such will play some part in the industrial development of the near future.

This means new developments in Quality Control, and the control operator who expects to keep abreast of the times will need to become familiar with the new technical developments in order to evaluate their effect upon his control activities. In particular there is the question of the relation of the statistical background of control to the new developments. The main answer can be given quickly, "The same laws of probability and the same principles of statistics will continue to apply." However, new statistical techniques which will increase the efficiency of the control operator are also part of the war and post-war development. These filter down to the operator level in a steady stream from the research frontier at which they are developed. Operators become familiar with them through local society meetings, magazines, and training courses available in colleges and universities.

It is obvious that while fundamental bases of Quality Control remain the same, the changing character of the goods sampled and the manufacturing processes employed must introduce new kinds of inspection methods and new standards of quality. For example, where formerly tensile strength in a product might be the only desideratum, with new knowledge non-shrinkage, imperviousness to moisture, absence of friction, etc., may be demanded in addition. In another product where hardness was thought to be a necessary accompaniment of elasticity, the former may now be greatly reduced without undue diminution of the latter. Such considerations will result in new opportunities for the Quality Control Engineer to suggest new avenues of investigation and to test in practice the results of engineering innovations.

At the same time it is likely that new processes, new materials and new manufacturing conditions will cause modifications of systems of quality control already set up. The rank and file operator has always placed great reliance in a more or less intuitive way upon the universal applicability of the normal symmetrical distribution of industrial variability. New processing methods may produce significant departures from the usual symmetrical form. Improved sampling methods have given additional precision and enhanced importance to receiving inspection departments. Thus, although fundamental principles remain the same in Quality Control, success will go to the Quality Control Engineer who knows the reasons for the use of the formulae, who understands the tables, who knows why control limits are placed where they are, in other words, who knows something about the theory which underlies the operation of Quality Control systems.

This situation will also test the business acumen of company executives. Those who have refused to pay adequate salaries to hire men of intelligence for Quality Control work, those who have adopted the attitude that any $25 clerk can draw a chart, are faced with the possibility of unforeseen difficulties. Those who imagined that once a system was installed the need for a trained Quality Control Engineer was ended will be paying large fees to consultants to locate the breakdowns in their systems. On the one hand their Quality Control staffs will be unable to adapt themselves to changing conditions and on the other hand Quality Control will have become an increasing necessity under new forms of competition.

To the Quality Control Engineer we say: (1) Renew your study of engineering, chemistry, physics; (2) Increase your knowledge of statistical theory underlying quality control.

ROBERT RIEGEL
University of Buffalo

Quality Control In The Manufacture Of Ball Bearings

CHARLES R. SCOTT, Jr.

S. K. F. INDUSTRIES

To acquaint you somewhat with the complexity of control in the manufacture of ball bearings, let us think roughly of 700 or 800 machines grinding 200,000 parts each day, to a tolerance of two or three ten thousandths of an inch. Considering the variability of men, machines, and materials, we realize that perfection is impossible, yet scrap and reoperation are costly and material is scarce. We are also confronted with the problem of measuring and comparing these thousands of parts. On a single race there are perhaps thirty to fifty individual inspection operations from tolerances of two or three thousandts of an inch to two or three ten thousandts of an inch; hence there are many variables that must be controlled. The foremost item that we had to dwell upon was to get the inspection data and investigation reports properly recorded. Inspectors especially had to be trained to fill out inspection forms as required for obtaining accurate statistical data. In the past, practically all of the measurements made upon our product were lost as far as use was concerned. It was difficult to change inspection thinking from sorting good from bad, to obtaining and recording true data of the actual measurements. In a number of instances we changed from "Go" "Not Go" type of inspection to dial indicators in order to get more accurate data. We found that accurate inspection information, if used properly, can help to prevent defects from being made in the first place.

Good quality control maintains the desired standard of quality by the inspection of raw materials, parts in process, assemblies, and the equipment supplemental to manufacture. It must be remembered that in the attainment of quality, as in anything else, there is a law of diminishing returns; as perfection is approached cost rises to disproportionate heights, consequently quality production must be reconciled with quantity production.

At the expense of repetition it might be pointed out here that the characteristics which go to make up good quality must be built into the product by the operator in the first place. No amount of inspection can change the quality already produced. The fundamental purpose inspection serves, is to measure quality for the protection of the customer and to present to Management a picture of the quality produced. The maintenance of accurate records of inspection results is costly, but, if from them procedures can be established on a scientific basis, thereby reducing the amount of actual inspection necessary, the cost is justified.

The ultimate plan of the new set-up in our plants was to transfer the responsibility for control and quality to a separate organization known as the Quality Control Department. The exercising of the different phases of these responsibilities, the place at which controls are established, and the kind and amount of control, are somewhat different from the old set-up. In the new line up, responsibilities such as methods and procedures, applications of statistical control, sampling, etc., are handled by the Quality Control group. It should be borne in mind, however, that these transfers of responsibility do not in any way affect the overall responsibility for quality, which is fundamentally up to the operator. All the quality characteristics must be built into the product in the first place, and the purpose of inspection is only to measure quality.

One of the chief duties vested in the Quality Control organization is to set up and administer quality techniques at the most effective points in our processes and assembly. With this thought in mind, our present organization evolved. We have a Quality Control Supervisor who is fundamentally responsible for control procedure and methods in all plants. Reporting to him are the Foremen of Quality Control situated in each plant. It is the responsibility of the Foremen to guide and direct the general principles for quality achievement in each of their respective plants. These men have as assistants to them, quality control engineers who are technical graduates with a thorough knowledge of the manufacturing processes. Control inspectors are employed whose main duties are to conduct quality investigations.

Objectives

We feel that if the following points are controlled, a quality product will naturally follow. The extent to which these points can be controlled, will determine the quality level attained.

1. The operator who makes the product — control inspectors by small distrbutional measurements frequently check to see how the product is distributing itself between the maximum and minimum limits.
2. Engineering requirements — by the establishment of operating bogies the allowable percent which the product can deviate from engineering requirements can be set.
3. The stages at which checks on inspection are made—the sequence in which inspections are made and the amount of inspection to be made are established and controlled.

4. Inspector's reliability — the reliability of the Inspector as a finder of defects should be checked to determine his overall job performance.
5. Tools and gauging equipment — the checking and maintenance to guarantee reliable inspection equipment should be systematically performed.
6. Percent of defects in product — by finished stock checks where the actual percent of defects shipped to the customer is studied, further inspection control can be placed on the process.

Organization

The general organization plan for supervising the performance of these responsibilities, as we have mentioned before, is to have a quality control foreman in each of the plants reporting to the Supervisor of Quality Control. For proper administration these duties can best be performed by making a separate organization of the Quality Control group. The Supervisor of Quality Control reports directly to the Factory Manager and therefore is not subordinate to either Inspection or Production. This freedom allows him to function without any partiality in the placing of controls or in the performance of the detail of the control toward either Inspection or Production Departments. Before this change in the organization was made, we very often found a tendency on the part of the quality men to favor inspection and try to cover up errors on the part of an inspector. It is the function of people we call Control Inspectors to make inspector rechecks, to take necessary distributional measurements upon the operator's product, and to set standards about which there may be a question between two departments. The Control Inspector has a very definite responsibility in reporting problems which may arise during the course of a quality investigation. He may be able to handle these problems himself or it may be necessary to forward them to the Quality Control Engineers. These men are interested in the amount of inspection being performed on any characteristic. Sorting or detail inspection is an expensive operation and an analysis of control reports would indicate whether this sorting is necessary. On the other hand, it may be necessary to suggest sorting operations, replacing sample inspection. In other words, one of the functions of the Quality Control Department is to say how much inspection and where. The question as to how good the inspection job is being performed, is answered by means of an inspector's reliability check. This is a standardized method of random check inspection whereby each inspector's dependability is measured. It has been proven that it is just as necessary to check the dependability of an inspector as it is to check the dependability of the measuring equipment. The inspector's work is checked at frequent intervals and the quality rating number is established. Sufficient data from this source have enabled us to weed out inspectors who did not prove to be sufficiently accurate. Regardless of the type of inspection operation, the operator's effectiveness depends upon his or her ability to detect all defectives in the lot. The checker compiles an actual reliability record for each inspector checked.

Reinspection

It is logical to check an inspector's performance by reinspection of his or her work shortly after the original inspection has been completed, and, of course, without the inspector's prior knowledge that the check is going to be made.

The checker's sample ordinarily consists of 100 pieces, which, of course, may vary depending upon the lot size, except in the case of statistical sampling inspection, in which case the inspector's entire sample is checked. It is most essential that no item of performance be overlooked, therefore, the checker actually does all the inspector is supposed to do. The mere fact that an inspector does more or less than is actually required does not alter the checker's requirements. When errors are found the checker makes out a report for the Quality Control Supervisor, with a copy for the Inspection Department Foreman. A separate cumulative data record is maintained by each checker for all inspectors checked, for the use of Inspection Foremen at intervals.

Gauge Control

Another important phase in Quality Control is the establishment of a gauge and standard section. It is the duty of this section to maintain the accuracy of measuring instruments and masters. A gauge in good condition is one of the most important control factors at the Inspection Supervisor's command. The one thing demanded is that gauges be kept accurate and in serviceable condition. A card record is set up for each micrometer, master rod, master disc, in fact, for all types of measuring equipment. Each gauge is identified by a serial number and a card record is maintained containing all the information pertinent to an accurate knowledge of the condition of such equipment at all times. The Inspection Supervisor should assure himself that the checking schedule established for the equipment is adequate for his purpose and should never hesitate to request a check of the equipment when there is any doubt as to its accuracy. Much of the trouble with gauges is due to misuse by the operator or inspector. A roving inspector is provided with a cart which is outfitted with the necessary instruments for checking gauges and equipment. This inspector travels through the Production and Inspection Departments checking gauges on the floor and records this information on the gauge inspection record cards. The data on record cards enable us to know just how frequently each type of gauge needs to be checked and from this we can establish predetermined checking frequencies.

Quality Records

One of the most important functions of our Quality Control Department is to keep production supervisors informed of their quality requirements and quality deficiencies which are reported by the various inspection groups. The method set up to convey this information to the interested parties, is handled partially as previously explained by the Control Inspector. The Control Inspector should first endeavor to make a cooperative contact with the Inspection and Production Departments. When the Inspection Department rejects a lot of material the Quality group is notified and an investigation immediately starts. The results of this quality investigation are reported on an investigation report. This report is forwarded to those parties

interested in correcting the procedure or error and a copy is placed on file in the Quality Department office. An attempt is made in this report to determine whether the defect was caused by personnel, material, or equipment. It may be that the parties upon whom the responsibility for the error was placed, disclaim responsibility for it. In this case, the Quality Control Supervisor must act as a referee and demonstrate that he is impartial with regard to Production and Inspection.

As a further means of keeping Management informed of quality results, the Quality Control Department is responsible for issuing results of work produced. The responsibility for Control rests with the operating inspecting divisions and the correct recording and interpreting of these results is often the difference between controlled and uncontrolled quality. Such a system is naturally costly to maintain, but if effective use is made of it, the cost will be more than justified. The first or fundamental record of quality is that which is recorded daily by each inspector. On this report the inspector notes the result of each job he inspects. Obviously, if this report is in error, the whole system will be based upon false premises. These records are tabulated daily by the clerical group and broken down into the various characteristics which go to make up the product. This is distributed weekly in the form of a control chart, which shows the amount of work offered for inspection, the number of pieces actually handled, and the number of defective pieces. This report is issued to all factory supervisory personnel. By the observation of trends it is possible from these reports to study conditions which are becoming critical with regard to rejections. The Shop Personnel and Control Inspectors use these for determining if the inspection is sufficient, or if process changes must be instituted. In addition to this a monthly quality report is compiled from the weekly summaries, and items which are out of control or have exceeded the established bogies are pointed out for action. Copies of these are distributed to Top Management as well as to factory personnel. In addition to these weekly and monthly survey reports, departmental supervisors are notified immediately upon the rejection of a lot, by the lot rejection ticket. The inspector fills this out immediately upon the rejection of a lot and thus the foreman has time to prepare an investigation before the trail has grown cold. We have found that much of the good of reporting results is lost if the production foreman does not know of the rejects before the end of the week. About once a week a small informal Quality Meeting is held at which time rejected lots are discussed. This immediate information through the lot rejection ticket and the informal review at the end of the week makes a very valuable liaison. At no time therefore, can the Production Department claim lack of knowledge of what operators are doing.

Control of Purchased Material

Since we must purchase from outside manufacturers considerable quantities of parts that go into assembly of bearings, a control chart is maintained on each of our suppliers. Compiling statistical data from our inspection of this material, a complete record is available of the quality furnished by every supplier. These are fraction defective charts and upon each line of purchased materials an acceptance specification is established. Very often information of this type has proved of considerable value when discussing with our suppliers their quality over the past year. Of course, there are a few added attractions that are bought with the maintenance of this type of information. For example, if a manufacturer consistently produces material better than the acceptable quality, it is possible to reduce inspection. If a manufacturer consistently produces material worse than acceptable quality, inspection becomes more severe, in order to reduce the risk that defective material may be accepted through the laws of probability. For most of the inspection done on purchased material we use the Dodge-Romig Lot Tolerance Tables, although some investigation is now under way to determine the applicability of Sampling by Sequential Analysis. In some cases we have found it advisable to inform our suppliers of statistical methods of Quality Control. We have a Quality Control man whose sole duty is to call upon our various suppliers at periodic intervals to inspect the work and gauges used by the supplier in an endeavor to prevent defective material from being shipped to our plant. This man attempts to keep close alliance between our standards of acceptance and those of the suppliers.

Quality of Finished Product

A further inspection is made of the finished product in stock. This inspection is of relatively small samples, usually 3% to 5% of each line of product, but is made in considerable detail. The picture presented is in the form of rates, the seriousness of the defect being weighted with a demerit value. For outgoing quality the demerit values are assigned by the Quality Organization and agreed to by the Final Inspection Department. A complete list of defects and their respective demerit values are given to the control men who remove finished parts from stock and perform their check. Controls are established in the form of bogies for expected quality levels with which these rates are compared. Generally, after a period of a year, or perhaps longer, depending upon the time required to get a representative picture, a base period is established. Limit lines are drawn about the base period or expected quality level to define the amount of variation due to chance which we may expect. For this purpose two sigma control lines are used. The Control Inspector doing this check must make certain that the distribution of the samples taken during the month is representative of the product being produced and is proportional to the output, otherwise a false quality picture will result. A report like this allows us to know just what the quality results of our Inspection Department are, and also shows us the quality level of the material being shipped to the customer. By making the basis or demerit values the same in all of the plants, we can get a quality comparison between the various plants.

Control of Production

Considering the use of control charts in the factory operation we have found that except for a few places that it was not necessary to maintain the control chart. Rather we keep a control chart on the entire department for each characteristic and only when the depart-

mental control lines indicate an unstable condition do we study that characteristic by the use of control charts. Although on groove diameters, where we must by selective assembly, assemble the inner and outer race using a limited number of ball sizes, we do plot control charts. The Floor Inspectors maintain these charts on each machine. The control limits used on any one job are filed away for future reference to be used the next time that job is operated. By closely controlling the distribution of the inner and outer race diameters, we have been able to give our Planning Department information so that they can schedule orders in advance. By proper control we know that these pre-ordered balls will be used in the assembly program.

Due to space restrictions in bearing applications, quality improvement must arise from improved raw matericls and manufacturing processes. Unfortunately good steels and those of mediocre quality are superficially identical. Incoming steel is subjected to a series of examinations to uncover flaws of any type. During Receiving Inspection, each heat of steel is tagged, and this tag remains with the lot until all parts are assembled. We found in the manufacture of balls, especially, that statistical sampling inspection could be most economically used. As each lot of balls moves through the manufacturing process it is identified as steel coming from a certain heat. The chemical analysis of this heat is on file in the Laboratory. If during the sample inspection, any particular lot is found defective, all lots carrying that same heat number are submitted to 100% inspection. Intra-operation examination of each lot assures that no roving defect will be obscured by subsequent stages of the manufacturing cycle.

Conclusion

During the past few years we have proved to ourselves that there are many valuable aids to production and inspection that can be accomplished through statistical measures. We have a long way to go before we arrive at the smooth working, well coordinated organization we desire, but during the period of rapid expansion we wanted to assure ourselves and our customers that the quality of our product would be maintained. Quality Control has helped us accomplish this and in addition certain worthwhile economies have been effected in the inspection procedures. We know there is still much to be done and we are confident that Quality Control technique will be a very useful management tool in the trying period ahead.

Fraction Defective Of Battery Adapter Used In Handie-Talkie

FRANK A. PALUMBO and EDWARD S. STRUGALA

GALVIN MANUFACTURING CORP.

In a plant which is set up primarily for the assembly of finished products, and which purchases parts and subassemblies, the quality control department has two major jobs. Process control under these conditions means the investigation and correction of faults occurring in assembly operations. The other important function is to set up procedure for quality assurance of incoming materials.

This paper contains a report of the work done in solving the problem of failure of a purchased part to function. This was one of the first problems presented to a quality control department newly formed to deal with the quality problem within the plant. The part in question is a battery adapter used in the Handie-Talkie Radio Receiver-Transmitter.

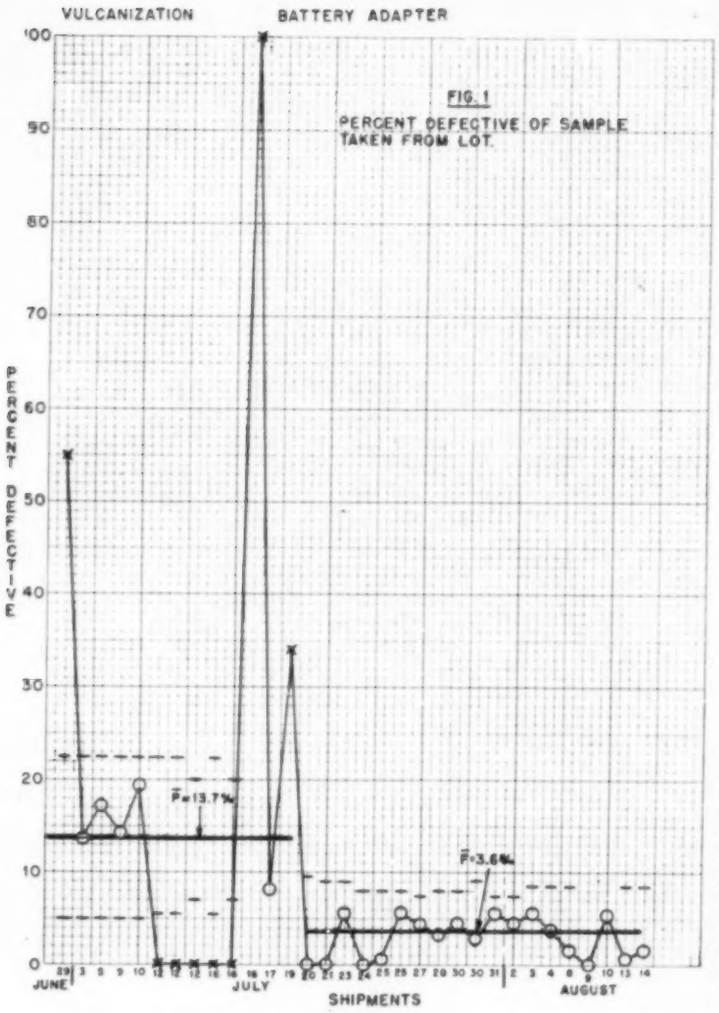
Description of Item

The battery adapter is a removable fixture, designed to hold two 1.5 Volt dry cells, the cells supplying "A" voltage to the set. It consists of a linen-base bakelite insulator onto which are riveted two metal arms. Both arms, a composition of beryllium-copper alloy, are silver plated; the positive arm coated with a rubber sleeving, the negative arm remaining bare.

Evolution of the Problem

Although this adapter had been purchased from the same vendor for some months and at no time had the quality been satisfactory, the contract was continued and the usable parts were sorted due to war-time production requirements. However, in June (1945) the Incoming Inspection Department reported a dangerous quality deterioration; dangerous because many lots were being rejected and the bank of parts in the crib was exhausted.

At this point the Quality Control Department was asked by management to participate in an investigation of causes of the trouble. The status of the case was about as follows: the article was not complicated; there were no very close tolerances; deficiencies in the plating and vulcanizing operations were stated to be the chief causes of rejections, although Incoming Inspection kept no records of causes of rejections prior to June 29; any correction of the trouble would require that a representative be installed in the vendor's plant; but quality records must be provided for this representative as quickly as possible.



Statistical Approach to the Problem

The sampling plan employed by Incoming Inspection was replaced by a somewhat unorthodox use of the Dodge-Romig Double Sampling Average Quality Table with A. O. Q. L. at 1% and process average assumed to be .81% to 1.00%. These selections in themselves forced the use of rather large samples, but in addition a further step was taken in the same direction. Both samples were taken from each lot and the entire combined sample was inspected for the two characteristics — plating and vulcanization. All of this was done for the purpose of acquiring an adequate quality record quickly.

The record of this inspection is shown in Tables 1 and 2. Table 1 shows that prior to July 20 eight of the lots were rejectable for faulty vulcanization and five were acceptable. But these five were rejected for poor plating as shown in Table 2 hence no lot was accepted during this period.

From these records per cent defective control charts were prepared in the form shown in Figures 1 and 2. The 3σ control limits computed in the usual way are shown at the right of Tables 1 and 2 and are plotted as dashed lines on Figures 1 and 2. During the period prior to July 20 the p values have very little meaning in terms of a satisfactory process, and the same is, of course, true of the control limits. Nevertheless, these charts aided in making the situation clear to the vendor.

Table 1

Results of Receiving Inspection of Battery Adapter and Control Limits for Fraction Defective Chart

QUALITY CHARACTERISTIC: VULCANIZATION

PRIOR TO PROCESS CHANGES

Date 1945	Lot Size	Sample Size	No. of Rejects in Sample	% Rejection	Upper Control Limit	Lower Control Limit
6-29	340	140	77	55.0	22.4	5.0
7-3	241	140	19	13.6	22.4	5.0
7-5	241	140	24	17.1	22.4	5.0
7-9	231	140	20	14.3	22.4	5.0
7-10	231	140	27	19.2	22.4	5.0
7-12	462	155	0	0	22.1	5.3
7-12	462	155	0	0	22.1	5.3
7-12	693	210	0	0	20.4	7.0
7-16	429	155	0	0	22.1	5.3
7-16	693	210	0	0	20.4	7.0
7-16	96	50	50	100.0	28.3	0
7-17	66	50	4	8.0	28.3	0
7-19	92	50	17	34.0	28.3	0
		1735	238			

AFTER PROCESS CHANGES

7-20	120	90	0	0	9.5	0
7-21	231	105	0	0	9.1	0
7-23	231	105	6	5.7	9.1	0
7-24	462	155	0	0	8.1	0
7-25	462	155	1	0.6	8.1	0
7-26	462	155	9	5.8	8.1	0
7-27	693	210	9	4.3	7.4	0
7-28	462	155	5	3.2	8.1	0
7-30	462	155	7	4.5	8.1	0
7-30	231	105	3	2.9	9.1	0
7-31	693	210	12	5.7	7.4	0
8-2	924	190	9	4.7	7.6	0
8-3	462	125	7	5.6	8.6	0
8-4	462	125	5	4.0	8.6	0
8-8	462	125	2	1.6	8.6	0
8-9	231	75	0	0	10.0	0
8-10	231	75	4	5.3	10.0	0
8-13	473	125	1	0.8	8.6	0
8-14	462	125	2	1.6	8.6	0
		2565	82			

Engineering Approach to Problem

Upon the arrival of our engineer, the production manager of the vendor's plant took him through the various departments. Production was at a veritable standstill, and 30,000 adapters were in all states of corrosion and disrepair. The only activity at this time was the removal of the rubber from rejected units. Further examination of accumulated parts disclosed that four or five different production processes and repair methods were employed. An inexperienced plater had the contract to silver plate the beryllium-copper straps; however, the plating method resulted in the flaking off of the plating. To remedy this defect the contractor attempted plating with an under plate of nickel as a base for silver. This method proved to be unsuccessful.

In addition to this difficulty, the plater placed rejected units into plating tanks in order to cover up previously unsatisfactory work. Again the process failed, for the seepage of cyanide loosened the rubber and removed the silver from underneath. The corroded and tarnished units, due to high cyanide and sulphur content, were given a cyanide bright-dip to improve the appearance of the plating; however, this treatment resulted in the removal of silver down to the nickel. All in all, the plater was unable to produce satisfactory results. This difficulty was removed by changing to a new plating company.

The rubber application on most of the original units was satisfactory except for those cases where they had been replated or bright-

(Continued on Page 14)

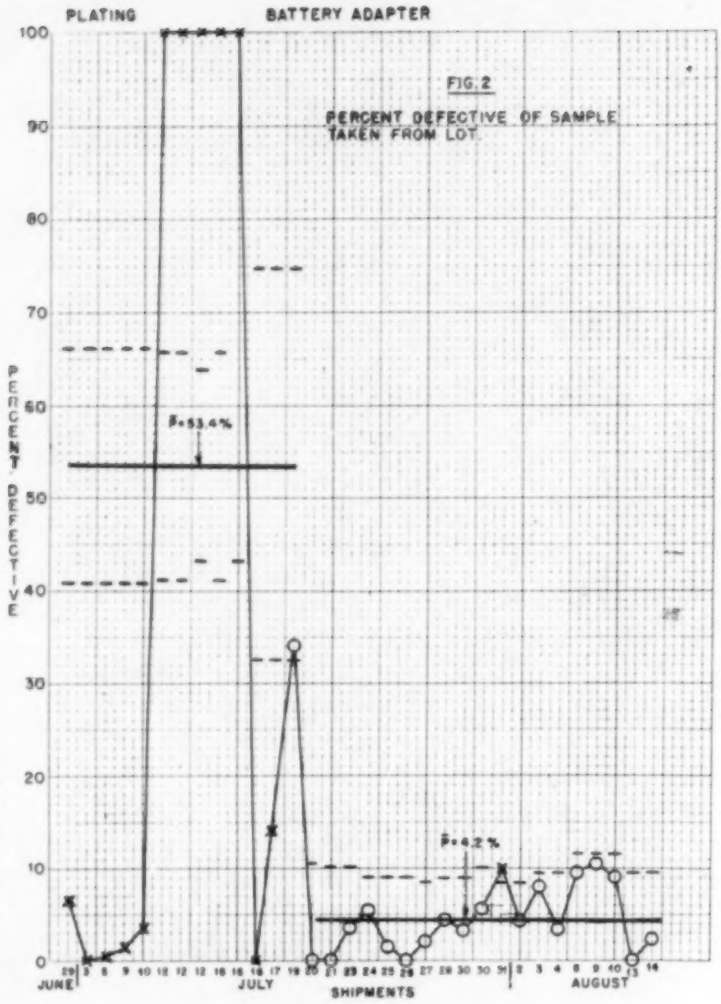


Table 2

Results of Receiving Inspection of Battery Adapter and Control Limits for Fraction Defective Chart

QUALITY CHARACTERISTIC: PLATING

PRIOR TO PROCESS CHANGES

Date 1945	Lot Size	Sample Size	No. of Rejects in Sample	% Rejection	Upper Control Limit	Lower Control Limit
6-29	340	140	9	6.4	66.1	40.7
7-3	241	140	0	0	66.1	40.7
7-5	241	140	1	0.7	66.1	40.7
7-9	231	140	2	1.4	66.1	40.7
7-10	231	140	5	3.5	66.1	40.7
7-12	462	155	155	100.0	65.4	41.0
7-12	462	155	155	100.0	65.4	41.0
7-12	693	210	210	100.0	63.7	43.1
7-16	429	155	155	100.0	65.4	41.0
7-16	693	210	210	100.0	63.7	43.1
7-16	96	50	0	0	74.6	32.2
7-17	66	50	7	14.0	74.6	32.2
7-19	92	50	17	34.0	74.6	32.2
		1735	926			

AFTER PROCESS CHANGES

7-20	120	90	0	0	10.6	0
7-21	231	105	0	0	10.6	0
7-23	231	105	4	3.8	10.1	0
7-24	462	155	8	5.2	9.0	0
7-25	462	155	2	1.3	9.0	0
7-26	462	155	0	0	9.0	0
7-27	693	210	4	2.0	8.4	0
7-28	462	155	7	4.5	9.0	0
7-30	462	155	5	3.2	9.0	0
7-30	231	105	6	5.7	10.1	0
7-31	693	210	21	10.0	8.4	0
8-2	924	190	8	4.2	8.6	0
8-3	462	125	10	8.0	9.6	0
8-4	462	125	4	3.2	9.6	0
8-8	462	125	12	9.6	9.6	0
8-9	231	75	8	10.7	11.2	0
8-10	231	75	7	9.3	11.2	0
8-13	473	125	0	0	9.6	0
8-14	462	125	3	2.4	9.6	0
		2565	109			

Limits For Control Charts

PRESTON C. HAMMER, PROBITY ENGINEERS

1. **Introduction**

The man who first tries to set up statistical control charts in his factory using only the standard methods may be puzzled when he finds that some of his limits are so wide that only a major catastrophe could produce a point outside the limits or he may be equally puzzled when the limits are so narrow that practically no points fall inside them. In either event the limits serve no purpose except perhaps to reap ridicule for statistical methods and their advocate. The author, having found both of these conditions in practical applications, is interested in showing why certain limit formulas cannot be applied blindly and ways of obtaining satisfactory limits. Useful variations of the average chart are also presented. All nomenclature and constants not defined in this paper appear in (Reference 1) at the end of the paper.

2. **Percentages of rejections: p-chart**

Let the variable p denote the fraction defective in certain lots of a manufactured article. Let n denote the number inspected which yields a fraction defective of p. Let $\bar{p}$ be the average fraction defective of a series of samples inspected. Is a given value of p significantly different from the average $\bar{p}$? The existence of a quality control engineer is partly justified by his ability to answer this question. The significance levels generally proposed are

$$\bar{p} \pm 3\sqrt{\bar{p}(1-\bar{p})/n}$$

If the fraction defective of a particular sample falls outside this range, action of some sort is indicated. These limits were developed from the binomial distribution theory.

In practice, however, one is not justified in assuming that control charts based on the binomial distribution are applicable to all cases in which materials are sorted into acceptable and unacceptable classes. Some illustrations will help to point up this statement.

Illustration 1 Suppose that 1000 ball bearings comprise a lot of which 40 are defective. The fraction defective obtained from the inspection of unbiased samples of 50 (samples being replaced after inspection) will follow quite closely a binomial distribution. If in a manufacturing process defective parts can be expected in a random fashion where "assignable causes" have been removed, then the binomial distribution is a good model on which to posit significance levels.

Illustration 2 Suppose that an inspector has taken an unbiased sample of 50 parts from a lot of 1000 parts formed on a punch press. This is a different operation and it is quite likely that either all of the parts will be acceptable or all of them unacceptable. A press that has been set up correctly and to which stock is being fed correctly should produce 100% good parts unless some assignable cause enters. But an assignable cause such as die damage, camber in the stock, or waste particles on the base anvil are almost certain to result in 100% scrap. Such condition can go on for a considerable period because the operator of a battery of machines has no time to check product at frequent intervals. A record of fraction defective of, say, 25 samples might show 17 samples with no defects, 3 or 4 samples with one defective, and the remainder 100% defective. Obviously an average fraction defective of the 25 samples has no meaning. Even if the rejected samples were excluded, the average fraction defective and control limits of the remaining samples would have little industrial value. This is a case that calls for action based on study of causes of rejection of individual samples. The use of the binomial distribution control chart is not recommended.

Illustration 3 In some instances there is an advantage in charting the percentage of rejections of all units produced in a given manufacturing area. In the manufacture of aircraft, for example, thousands of different parts are produced in small lot quantities. The number of parts makes it impracticable to keep a chart on each part; hence charts are kept by sections and points may be posted but once a week. Specifically, suppose that the punch-press section averages an output of 1,000,000 units a week, these units being unequally divided among 1000 distinct parts. Let us compute the regular p-chart limits assuming an average defectiveness for a past period of 4%. The limits, using $\bar{p} = .04$ and $n = 1{,}000{,}000$, are 3.94% and 4.06%. Anyone remotely connected with manufacturing would suspect that these limits are absurd. As a matter of fact the occurrence of a point within these limits might well be considered unusual. It has been argued "if the process were in control these limits would work." The universe (a battery of presses performing 1000 different operations with each press reset and the dies changed many times during the week) is not sufficiently homogeneous (in the sense described in Illustration 2) to expect chance variability within the stated limits. A multitude of assignable causes are submerged in the weekly totals.

Further, this example meets the criteria for a Poisson distribution. Why not shift from the binomial to the Poisson? Four per cent of 1,000,000 is 40,000 and 3σ limits would give an expected chance variability of 600 units. But these are the same limits as were obtained for the binomial. Moreover the formula

$$c \pm 3\sqrt{c}$$

cannot be used where c is 40,000 and no solutions of the Poisson for such large values are available; hence there is nothing here that can be used in the shop.

This situation was met by the development of the **Moving Range Method**, a simple adaptation of the average and range charts which has proved servicable in many situations.

3. The Moving Range Method

Let us assume that a sequence of variates $X_1, X_2, \ldots, X_k$ have occurred in a random sampling of a normal population. An estimate of the standard deviation of this population may be obtained by grouping these variates in successive groups of, say, n variates and computing R from the ranges of these groups. Then the estimated standard deviation is $\overline{R}/d_2$ where d_2 is taken for a sample size n (Reference 1.) The three sigma limits for this sequence of variates are given by $\overline{\overline{X}} \pm \sqrt{n} A_2 \overline{R}$.

In practice, for indicating significance limits for individual values, we have found it desirable to group the sequence by twos (n = 2) and also to take an overlapping rather than exclusive grouping. Thus ranges are computed from the groups (X_1, X_2), (X_2, X_3), (X_3, X_4) and so on. The reason for an overlapping grouping is that from our initial assumption there is no preference for using an exclusive grouping starting with the first two rather than an exclusive grouping starting with the second and third values. As either method of exclusive grouping would lead to equally valid estimates of the standard deviation it follows that by using the overlapping method a more reliable estimate of the standard deviation is obtained. Since this overlapping grouping coincides with the one used in computing moving averages, we term this method the moving range technique.

Let us illustrate this method by a set of percentages. We shall assume that the percentage defective established each week is per se a measure of quality which should vary about a central value in accordance with some distribution. We ignore the sample size, we disregard the binomial distribution, and proceed to set limits based on the variability exhibited by the percentages themselves. Now, if points are plotted infrequently (say daily or weekly) it may be economical to investigate deviations within the 3-sigma control limits. For percentages plotted weekly we have found 2-sigma limits to be well adapted for a significance level, the theory indicating that, for a normal distribution, about one point in twenty will fall outside such limits due to random deviations alone. It is clear that the less frequently points are posted on the charts the greater attention can profitably be paid to relatively small deviations and short trends. In this example we shall use 2-sigma limits, our limit formula for n = 2 being

$\overline{\overline{X}} \pm 2/3\ (\sqrt{2})\ A_2 \overline{R} = \overline{\overline{X}} \pm 1.77 \overline{R}$.

(Note. this expression could be replaced by its equivalent $\overline{\overline{X}} \pm 2\sigma'$)

Example:

Sample No.	Percentage Defective	Moving Range
1	2.3	
2	4.7	2.4
3	1.5	3.2
4	3.9	2.4
5	5.2	1.3
6	4.6	.6
7	4.0	.6
8	5.5	1.5
9	3.1	2.4
10	4.2	1.1
11	5.6	1.4
12	3.5	2.1
	48.1	19.0

$\overline{\overline{X}} = 48.1 \div 12 = 4.01$

$\overline{R} = 19.0 \div 11 = 1.73$

UCL $= 4.01 + (1.77)\ (1.73) = 7.07$

LCL $= .95$

This moving range method has been used successfully on percentage defective charts for large sample sizes, on inspection output data, on rejections per unit, and on rejections per inspection operation. It probably cannot be used in percentage defective charts where the sample sizes vary from small to large. See (Reference 2) for actual examples of the use of the moving range on inspection output data and on percentage rejections. We recommend the moving range method with n = 2 to set limits for any time series of values which should be constant save for random variations. In such a time series there is generally no rational basis of grouping except contiguity in time. Thus the moving range method is logically adapted to such time series provided that the distribution of values does not depart too much from the normal curve.

Let us turn to one point as yet unsettled. Using the moving range technique, limits have been set on as few as 10 points although 12 or more are preferable. The average moving range will give a better estimate of the standard deviation than the customary average range. A measure of this advantage of the moving range has yet to be determined. Readers familiar with mathematical statistics will see in the moving range by groups of two a similarity to the mean square successive difference (Reference 3).

4. The Poisson Distribution and the c-chart

The questions raised in section 2 as to the general applicability of the binomial distribution as a model for percentage defective apply with equal force to the use of the Poisson distribution for variations in defects per unit. It has been shown by the author and by the experience of others in the aircraft industry that the Poisson distribution does not apply to the number of defects in certain assembly units. At Lockheed Aircraft Corporation the practice of using the moving range worked out satisfactorily. Other companies, resorting to the $\overline{X}$ and R charts, report good results. In any case, it is not safe to assume that the customary c-chart limits will be suitable for defects per unit or weighted defects per unit.

5. Useful Variations of the Average Chart

Generally speaking the percentage defective type chart tends to be a management tool. It is an aid in measuring the success of detailed efforts to control quality but it is less effective than other charts in indicating the action to be taken. The average chart and the range chart, on the other hand, are more useful analytical tools for locating sources of trouble and for indicating to the engineer, foreman, and operators the corrective action necessary. Less trouble has been encountered with limits on $\overline{X}$ and R charts than with the other types suggesting that the assumptions on which they are based form a more satisfactory model for variations in most cases. Even so, there are instances in which limits on these charts have been computed quite erroneously. In this section we present two simple variations of the average chart. In a later paper the question of $\overline{X}$ and R chart limits in comparatively complex situations will be discussed.

A case in which a deviation from the usual procedure for using average and range charts proved of benefit was reported by Professor E. L. Grant. A processing company made one analysis a day of a certain process. If the data were grouped for successive exclusive sets of four values, points would be posted but once every four days so that action might be taken too late when points fell outside the control limits. Assuming that the analysis was so costly that only one a day was feasible the problem was to maintain the advantage of narrow average chart limits and still post points daily. Professor Grant suggested the construction of a four day moving average chart and a four day moving range chart. The same formulas for limits were used as in the normal procedure. This method was found to work satisfactorily.

In the example mentioned it might seem desirable to give the last day's datum a greater weight than is given to the data of the preceding days. If this is to be done we may use a weighted average of the four values (more specifically a weighted moving average). To illustrate we shall give the weights 1, 2, 3, and 4 to the values respectively. If we are to use a weighted moving average we must modify the limit formula. This is simply done for if X_1, X_2, X_3, and X_4 are random variables with the same distribution, then the standard deviation of

$$1\ 10\ (X_1 + 2X_2 + 3X_3 + 4X_4)$$

is 1.10 times the standard deviation of the regular average $\overline{X}$. Accordingly the limits for the weighted average chart are

$$\overline{\overline{X}} \pm 1.10\ A_2\overline{R} = \overline{\overline{X}} \pm .800\overline{R}.$$

The moving range chart is left unaltered. A weighted average in this case has the advantage of emphasizing the most important point and at the same time having the more sensitive limits of an average chart. The limits, while slightly wider than the limits for an average chart are still much narrower than the limits for the individual values. This device will be found useful in many cases where measurements are taken rather infrequently such as every hour or every day.

In case the reader wishes to apply this procedure using a different sample size or different weights we shall give the development here for the general case. Let the weighted average of a sample of n values each varying independently of the others and all drawn at random from the same population be indicated by $\overline{X}_w$ and let σ_w denote the standard deviation of $\overline{X}_w$. If $w_1, w_2, \ldots, w_n$ are the constant weights,

$w_1 + w_2 + \ldots + w_n = 1$, and $\overline{X}_w = w_1 X_1 + w_2 X_2 + \ldots + w_n X_n$, and if σ is the population standard deviation, then we have

$$\sigma_w = \sqrt{w_1^2 + w_2^2 + \ldots + w_n^2}\,\sigma \qquad (1)$$

The standard deviation of $\overline{X}$ is $\sigma_{\overline{x}} = \sigma / \sqrt{n}$

Hence $\sigma_w = \sqrt{n}\ \sqrt{w_1^2 + w_2^2 \ldots + w_n^2}\,\sigma_{\overline{x}}$

The 3σ limits for the weighted average chart are

$\overline{\overline{X}} \pm 3\sigma_w = \overline{\overline{X}} \pm 3\sqrt{n(w_1^2 + w_2^2 + \ldots + w_n^2)}\,\sigma_{\overline{x}}$

But $3\sigma_{\overline{x}} = A_2\overline{R}$, hence the formula for the limits is

$$\overline{\overline{X}} \pm \sqrt{n(w_1^2 + w_2^2 + \ldots + w_n^2)}\ A_2\overline{R}$$

This formula is basic for the limits of a weighted average chart using ranges as a measure of variation. Once weights have been selected and the sample size determined, the value of

$\sqrt{n(w_1^2 + w_2^2 + \ldots w_n^2)}\ A_2$

is easily computed and is thereafter fixed.

To show how this system applies to get the limits in the particular example cited, take

$w_1 = 1\ 10$, $w_2 = 2/10$, $w_3 = 3/10$, $w_4 = 4/10$ and $n = 4$.
Substituting in the formula we have for the weighted average chart limits

$$\overline{\overline{X}} \pm \sqrt{\frac{4(1^2 + 2^2 + 3^2 + 4^2)}{100}}\ A_2\overline{R} \quad \text{OR} \quad \overline{\overline{X}} \pm .600\,\overline{R}$$

The restriction $w_1 + w_2 + \ldots + w_n = 1$ is necessary only to obtain a weighted **average**. Formula (1) holds without such restriction.

6 Conclusion.

In this paper we have shown why the quality control engineer must not uncritically apply limit formulas and have suggested what may be done to obtain limits for satisfactory levels of significance. The moving range technique (section 3) has been successfully applied to a variety of charts. It is a tool sometimes useful which the quality control engineer should have in his kit. The weighted moving average chart is destined to become more widely used for certain types of data. In the succeeding paper we shall consider a comparatively complex analysis of dimensions in which multiple measurements occur.

REFERENCES

1. A. S. T. M. Manual on Presentation of Data, Appendix B: "Control Chart" Method of Analysis and Presentation of Data. Tables for all constants used in this paper appear on page 50.
2. James R. Crawford and P. C. Hammer "Statistical Quality Control at Lockheed" Quality Control Report No. 9 published by W. P. B. Carnegie nstitute of Technology, Quality Control Program in September 1945.
3. J. Von Neuman, R. H. Kent, H. R. Bellington, and B. I. Hart. "The Meon Square Successive Difference" Annals of Mathematical Statistics 12: 153-162, June 1941

SOCIETY REPORTS

Delaware Quality Control Society

The October 16th dinner meeting of the Society, held at Hotel Rodney, Wilmington, was devoted to a discussion of "Producer-Consumer Risk and Volume of Sampling." The contributions of members on the probability background of sampling results, and the importance of controlled variability of process average made a profitable meeting.

Our Society joined the Wilmington Chapter of the Society for the Advancement of Management at Hotel Rodney, November 19, to hear Paul Peach, North Carolina State College, on Quality Control, A Management Tool. Mr. Peach was well received by the sixty-two persons present.

On December 3 Professor Irvin S. Hoffer spoke on the "Use of Control Charts to Study Unusual Variation in Production." Professor Hoffer's explanation of the interpretation of the control chart and the frequency distribution where the variability of a process is nonsymmetrical will be quite valuable to members of our Society.

Quality Control Engineers of Rochester

The October 16th meeting was attended by 215 people. This meeting was a panel discussion on Quality Control at Bausch and Lomb Optical Company. Mr. R. H. Eisenhart acted as chairman of the panel which was composed of Mr. Edward Close, Mr. Howard L. German and Mr. Joseph C. Warren. The Annual election of officers was held and the following were elected for the coming year: Alfred L. Davis, President, Rochester Institute of Technology; Halsey H. Kent, Vice-President, Camera Works, Eastman Kodak Company; J. A. Tilton, Secretary-Treasurer, Delco Appliance Division; Members of the Board: Elmer J. Abell, International Business Machines; O. H. Eiffert, Sargent & Greenleaf; John Farrant, Stromberg-Carlson; George Fowler, Ritter Company; Fred Nielsen, Taylor Instrument Company; William L. Myers, Gleason Works.

The Gage Control sub-group has held two meetings to date. The October 2 meeting was addressed by Chauncey G. Newton of Pratt and Whitney Company and his subject was, "Facts About Gage Procurement." The second meeting was held November 6 at the Walz and Krenzer Company. Captain E. E. Polider, chief of the gage section of the Rochester Ordnance District, was the speaker, his subject being, "Gaging Practice Considerations." This meeting was attended by 33 people.

On October 24 a new sub-group of the Quality Control Engineers was formed. The subject to be discussed by this group is Sampling. Mr. Lloyd Lawrence was selected as chairman of this group with Mr. Edward Close as co-chairman in charge of the program committee. A total of 44 people attended this meeting and it was decided to hold meetings of the group every two months.

At the November 20 meeting 206 persons attended to hear Louis C. Young, Westinghouse Electric Corporation, discuss "Charts to Allocate Responsibility for Quality." The feature of his talk was the point of view that the simplest control technique which will accomplish the purpose of maintaining quality marketwise should be adopted. In the post-war period quality control departments must justify their payroll expenditures in terms of value of product saved and rework cost avoided. These necessities will reduce the tendency toward experimentation and put emphasis on the simplest, most direct control procedures.

Northwestern Society for Quality Control

The sixth follow-up meeting was held October 11. Much time was devoted to organization matters of (1) The Local Society, (2) The Midwest Conference, (3) National Society. Mr. Frank Palumbo, Galvin Manufacturing Company, presented the method by which poor quality of a vendor's product was improved. (Editor's Note: Mr. Palumbo's story appears in detail elsewhere in this issue.) Professor Hildebrandt reviewed the principles of fraction defective charts.

The principal speaker at the November 28 meeting was Dr. Irving Burr of Purdue University. His subject was "Illustrating the Principles of Quality Control with Dice."

Syracuse Society for Industrial Quality Control

Syracuse has planned two types of meetings for its membership. One type will be a "members" meeting, in which general discussions will take place. This type of meeting is designed so that the member can air his current difficulties and possibly receive help from the other members. The other type of meeting will be an open meeting in which a speaker will be present and people other than members invited. It is planned to rotate the two types on a monthly basis.

A "members" meeting was held on October 30, 1945. The topic of discussion was "Who Should Set the Standards on Receiving Inspection." It was concluded that Inspection should set up the vendor's A. O. Q. L. and that, invariably, it was necessary to educate the Purchasing Department regarding desirable and undesirable vendors.

Business included the making and passing of a motion changing the name of the Society to "The Society of Quality Control Engineers of Syracuse" — this in line with the recent federation of Detroit, Rochester, Buffalo and Syracuse.

The third meeting of the fall series was a dinner November 27 at Hotel Syracuse. Mr. H. M. Adams, formerly of the Chrysler Tank Arsenal, spoke on "Building Fighting Tanks with Quality Control." The large attendance of members and guests, and the enthusiasm are significant criteria of the growing interest in quality control in this area.

Society of Quality Control Engineers of California

The new officers elected at the October 25 meeting are William B. Rice, Plomb Tool Company, President, and Dr. Preston C. Hammer, Probity Engineers, Vice President. William H. Lewis continues in the Secretary post. At the December 6 dinner meeting the following subjects were discussed: "Quality Control in Industrial Relations," V. D. Penland, "Quality Control Methods in Budget and Output Control," E. H. Bauer, "Review of New Develop-

ments in Quality Control," R. A. Wood.

Boston Society for Quality Control

Activity in the New England area came as an outgrowth of the Northeastern University Quality Control course. At a follow-up meeting on August 18, 1945, Professor Harold A. Freeman of the Massachusetts Institute of Technology discussed Sequential Sampling and four members of the group gave short talks on applications. A steering committee was appointed to help organize the group.

At a meeting held October 20, Mr. Ralph E. Wareham of the National Photocolor Corporation, New York, traced the history and development of Quality Control. Constitution and By-Laws were adopted and the group was formally organized with 80 members representing 35 firms. The following men were elected to form the Executive Committee: W. R. Purcell, President, Sylvania Electric Products Inc., Salem Plant; E. E. Haskins, Vice President, Professor of Mathematics, Northeastern University; M. D. Benedict, Secretary, General Electric Company, West Lynn Works; L. A. Sedar, Treasurer, General Electric Company, River Works; and C. J. Hudson, Representative to National Organization, Norton Company.

A meeting was held December 15 at Northeastern University. Professor George Wadsworth of M. I. T. discussed Control Methods and the value of Advanced Techniques. Mr. George J. Meyers, Jr., of Manning, Maxwell and Moore spoke on Quality Control Applications.

The Executive Committee wishes to express their gratitude to the many groups around the country who assisted in the work of organizing the Boston Society.

Newark Society for Statistical Quality Control

The first meeting of the 1945-46 series, held October 22 at the Essex House, was devoted to "Quality Control in Chemical Engineering." The principal speaker was Mr. John Mandel, the B. G. Corporation, on "Simple Tests of Significance and Applications to Analytical Chemistry." The spirited discussion which followed is adequate evidence of the broad interest in quality control in the chemical field.

The Newark Society has set up an employment coordinator whose function is to bring together quality control operators who are unemployed and representatives of firms seeking such operators. This service is being established to meet conditions arising from reconversion.

The Regional Conference of December 5 is reported elsewhere in this issue. We expect to find great interest in the meeting devoted to "Control of Penicillin Manufacture" on March 14, 1946.

Indiana Society for Statistical Quality Control

The Society's first fall meeting was held October 11 at Purdue University, Indianapolis Extension. The speakers were Mr. Robert Booton, United States Rubber Company; Dr. Irving Burr, Purdue University; Mr. F. J. Halton Jr., John Deere and Company; and Miss Ruth Replogle, Perfect Circle.

Mr. Booton explained the use of measurement charts in controlling production of Banbury Mix. The great barrier to good production was the plan of paying a flat rate to workers regardless of whether their product was usable or scrap. After study of the control charts management set up a wage plan which rewarded the operator who produced good quality and penalized the operator who produced poor quality. As a result the defective rate of Banbury Mixes was reduced from 30% to 3%. Production was increased by 10%. Lost time per machine was reduced from 220 minutes per day to 60 minutes per day.

Mr. Halton explained the method used in presenting the quality control point of view to top management. At a dinner attended by executives of all plants, the essentials of the Z 1.3 pamphlet were explained along with the operating plan of the Quality Control Department. Operators are sent to any plant upon request by the management of that plant. In one plant the use of charts demonstrated that machinery and equipment worth about $100,000 which was about to be scrapped as unusable really could do the job satisfactorily.

Dr. Burr presented in detail the use of correlation analysis to determine significant relationships in the production of steel. Miss Replogle explained the use of measurement charts in controlling tension of castings. Chart analysis led to the use of variance analysis to catalog significant causes of variability in quality of castings.

Chicago Society for Quality Control

The Chicago Society for Quality Control is maintaining monthly meetings which are of educational value to its members and friends. The following meetings have been held this fall and are representative of the active program which is planned:

September 12, 1945 — R. H. Schneberger of the General Electric Appliance Company discussed his experience of installing quality control in this company.

October 10, 1945 — H. J. Sprengel of the General Electric X-Ray Division discussed his use of variables inspection data for setting up reject and specification limits.

November 3, 1945 — F. J. Halton, Jr. of Deere and Company discussed the problem of presenting quality control to management.

These meetings have all been held at the Central YMCA, 19 S. La Salle Street, and are preceded by a dinner which affords the members an excellent opportunity for mutual discussion of their problems.

Ohio Quality Control Society

Dr. Edwin G. Olds, Carnegie Institute of Technology, spoke on "What Management Should Know About Quality Control" at the October 12 meeting. On November 23 Mr. William A. Bennett, Works Manager, English Needle and Fishing Tackle Company, and Maurice Milbourn, Research Department, Metals Division, Imperial Chemical Industries, spoke on "Applications of Quality Control Methods to British Industry." Both of these meetings were well attended, and both produced constructive discussions of well rounded main presentations.

A course, "Fundamentals of Quality Control," will be offered at Case School of Applied Science. This course presents an opportunity for newer quality control operators to acquire necessary background. It likewise serves as a welcome refresher for those who have had time to forget the details of courses taken earlier.

(Continued from Page 8)

dipped. Also, due to pressure from our plant to accumulate a backlog of the adapters, vulcanization time was decreased, resulting in poor bonding qualities. To insure satisfactory bonding between silver and rubber, definite periods of setting and aging were established.

The results of engineering application brought about the following improvements: (1) New methods of rubber applications evolved. (2) Standard procedures in both processes were established and agreed upon. (3) Material acceptable to us and to the Signal Corps was being manufactured.

Effect of Changes

These changes became effective on product reaching our plant on July 20. The results are obvious in the tables and charts. Despite the marked improvement, the quality of the material was not sufficiently high for acceptance under the sampling plan.

The lots received on July 20, July 21 and July 25 were accepted, but all of the others were detailed. On August 1 the A. O. Q. L. was raised to 3% and a new set of sample sizes and acceptance numbers was given to inspectors. This change was merely an acceptance of the inevitable. If this vendor could not produce at a better quality level, we had the choice of accommodating our acceptance level and assembly operation to his quality or of finding a new vendor. Management elected the first alternative. Under the new acceptance level all lots submitted during August were acceptable for vulcanization but the lots of August 3, August 8, August 9, and August 10 were detailed for plating.

After July 20 (Figure 1) the vulcanization operation was in control. This means that the process was stabilized at 3.6% defective. We assumed that improvement from that level could be obtained only by careful study of both equipment and procedure. However, a report was being prepared for the vendor pointing out the down-trend in per cent defective during August, when the Japanese surrender interrupted the whole program.

The story of Figure 2 is partially parallel, although the upward trend of per cent defective is apparent. We believed that plating would soon become troublesome unless further process improvement were undertaken.

Summary of Results

This story is, of course, incomplete, but the progress up to V-J Day might be stated as follows:

1. A basis of cooperative action was established between the Quality Control Department and Engineering.
2. The Incoming Inspection Department was given a favorable introduction to the use of a scientific sampling plan.
3. An acute assembly bottleneck was relieved at a time which might have been critical in the war effort.
4. Cooperative action for quality improvement between vendor and purchaser became a reality.
5. The value of the technique and point of view of the Quality Control Department was demonstrated to management.

LETTER TO READERS

The editor is delighted to bring to the attention of readers the following letter from Paul Peach.

Dear Professor Brumbaugh:

"As head of the Industrial Section of the Institute of Statistics of the University of North Carolina, I receive from time to time inquiries from industrial concerns, asking me to recommend someone to undertake quality control work in their plants. As the value of statistical methods in industry comes to be better known, I have no doubt that I shall receive an increasing number of such inquiries.

Although in time we expect to use these leads to place our own graduate students, at present we need the names of suitable candidates for such employment. I am quite sure that even at peak operation we shall be unable to turn out qualified students fast enough to satisfy the demand.

If you know of any suitable person qualified to do work in industrial statistics, quality control, and related fields, I should be glad to have him register with our Personnel Placement Office. I should be very happy to have you pass this invitation along through the columns of INDUSTRIAL QUALITY CONTROL." Yours sincerely,

Paul Peach
Industrial Section
Institute of Statistics

REGIONAL MEETINGS

Rochester Quality Control Clinic

The second Annual Quality Control Clinic, sponsored jointly by the Quality Control Engineers of Rochester and the Rochester Industrial Management Council, will be held February 19, 1946 at the Rochester Chamber of Commerce. The plan is to parallel closely the Clinic of last year with ten or more group meetings following luncheon and the main dinner in the evening.

The program of the Clinic will appear in the January issue of INDUSTRIAL QUALITY CONTROL. Information concerning the Clinic can be obtained from Mr. David Crockett, Manager, Industrial Management Council, Chamber of Commerce Building, 55 St. Paul Street, Rochester 4, New York.

Midwest Quality Control Conference

March 5 and 6, 1946 is the date of the first conference meeting of the Midwest Quality Control Societies. For this two day session programs are being prepared to present all phases of quality control operation. All sessions of the Conference will be held at the La Salle Hotel in Chicago.

The program of the Conference will appear in the January issue of INDUSTRIAL QUALITY CONTROL. Anyone desiring further information concerning the Conference should communicate with Lt. (jg) Jack Shafer, Publicity Chairman, Room 1500, Board of Trade Building, 141 West Jackson Boulevard, Chicago, Illinois.

Princeton Conference on Statistical Quality Control

A meeting sponsored jointly by the Delaware, Newark, Philadelphia and Princeton Societies was held at Princeton University, December 5. At the morning session the speakers were Dr. Frederick Mosteller, "Acceptance and Control Sampling," Mr. Joseph Manuele, "Process Control," Dr. A. E. R. Westman, "Quality Control and Research." The luncheon address was given by Mr. Andrew I. Peterson, "Economic and Management Factors in Quality Control." Two panel discussions were conducted during the afternoon, one on "Production and Inspection" with Mr. Ralph Wareham, Chairman; the other on "Design, Research, and Specifications" with Mr. E. H. Mac Niece, Chairman.

A NEW PUBLICATION PROGRAM

Quality Control operators have often been unable to secure direct information concerning quality control work being done in England. Such information is now to be made available through the Gryphon Press, 301 South Court House Road, Arlington, Virginia, which will carry stocks of English Statistical Books.

Two booklets are now available: (1) "Quality Control Chart Technique When Manufacturing to a Specification," B. P. Dudding and W. J. Jennett, General Electric Company Limited (74 pages, $1.00). (2) "Quality Through Statistics," A. S. Wharton, Philips Lamp Inc. (60 pages, $1.50).

The first pamphlet contains a very complete exposition of control technique and is so written that persons having no previous knowledge of statistical control methods can use it as a primer. At the same time readers are carried by easy stages through a series of applications of control technique to both measurement and fraction defective inspection records. Emphasis is placed on the correct use of the relative precision index (R.P.I.), an efficient form in which to establish the relation of the variability of a process to the specification tolerance.

The second booklet contains a combination of the operating principles of statistical control and the basic point of view of the subject. Like the first pamphlet, it is nonmathematical and devoted wholly to in-plant applications. Many innovations in procedure are explained. Some of these are directly applicable in American plants, others can be used with modifications. Perhaps the most valuable single feature of the pamphlet is the author's sound philosophy concerning the place of statistical control and the attitude of management.

NEWS ITEM

The intensive 10-day course in Industrial Statistics and Quality Control at North Carolina State College, Raleigh, ended Oct. 26, 1945, with 29 registered students.

This course was of special interest for two reasons. First, it was an attempt to give such courses on a pay-as-you-go basis. Previous courses of this kind were subsidized by the federal government; the N. C. State course charged a tuition fee of $50.00 and finished slightly but definitely in the black. Moreover, it now appears that the fee for future courses of this kind might even be somewhat reduced and still pay expenses.

The second point of interest was the material presented. Previous courses have concentrated on chart control methods, with a diminished emphasis on acceptance sampling; the aim has been to give students a thorough drill in a few fundamental techniques. The N. C. State course concentrated on the theory of testing hypotheses, using acceptance sampling as a basis, and touched briefly on a number of statistical techniques in addition to the control chart, the idea being to introduce the student to a variety of tools, leaving him to gain proficiency in their use through actual experience. A special textbook was supplied in order that students might have some reference material beyond their lecture notes.

The value to industry of courses using the new approach remains to be determined by experience. There is probably a place for both types—the one, emphasizing chart control techniques, aimed at the production and inspection levels; the other, more general in its scope, for the engineering, technical, and research groups.

NOTES

Peter Di Paola formerly in charge of the Statistical Quality Control section at Curtiss-Wright's Kenmore Plant has joined the faculty of the Long Beach New York High School as an instructor in Physics and Personnel Supervisor.

Edwin G. Olds has completed his work with the Office of Production Research and Development of the War Production Board and has resumed his position in the Mathematics Department at Carnegie Institute of Technology.

Holbrook Working has completed his work with the Office of Production Research and Development of the War Production Board and has resumed his work in the Food Research Institute at Stanford University.

Alfred J. Heitner has been appointed to an Advanced Development Group by Sylvania Electric Corporation and has been transferred from Emporium, Pennsylvania to the company's Long Island laboratory.

Ralph Wareham has resigned as Quality Manager of General Electric Corporation at Schenectady and has launched a private consulting service in quality control.

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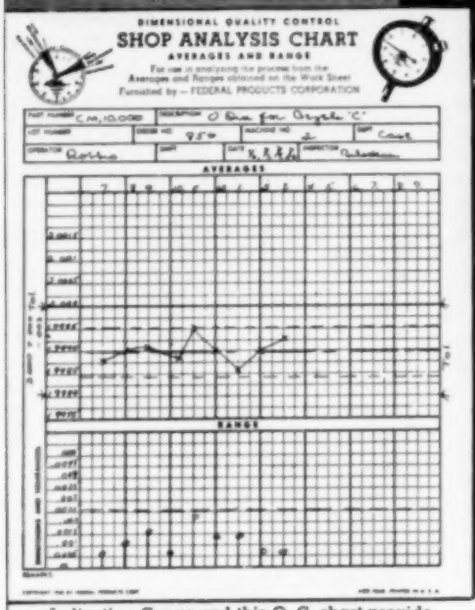

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